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This award supported research on modeling nearshore processes as complex systems. This research was motivated by the observations that the processes operating in the nearshore are dominantly nonlinear and dissipative and that the nearshore often exhibits behavior that is not linearly connected to forcing by incident waves. The hypothesis that the nearshore is a complex system was explored by (I) research on the general properties of complex systems and their relationship to natural systems, (ii) modeling bedforms, (iii) continued analysis of measurements from experiments testing a self-organization and standing edge wave models for beach cusp formation, and (iv) initial (and ongoing) development of complex systems models for infragravity wave generation in the surf zone and coupled sand bar and shoreline evolution.

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FINAL REPORT:

Modeling Nearshore Processes as Complex Systems

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This award supported research on modeling nearshore processes as complex systems. This research was motivated by the observations that the processes operating in the nearshore are dominantly nonlinear and dissipative and that the nearshore often exhibits behavior that is not linearly connected to forcing by incident waves. The hypothesis that the nearshore is a complex system was explored by (i) research on the general properties of complex systems and their relationship to natural systems, (ii) modeling bedforms; (iii) continued analysis of measurements from experiments testing a self-organization and standing edge wave models for beach cusp formation; and (iv) initial (and ongoing) development of complex systems models for infragravity wave generation in the surf zone and coupled sand bar and shoreline evolution.

The second year of funding from this grant was not awarded by mutual agreement because the principal investigator is part of a team (with John Orcutt) receiving a Secretary of the Navy / Chief of Naval Operations Chair/Scholar Award that funded related research.

COMPLEX SYSTEMS

Nearshore processes are nonlinear and dissipative. For systems with these characteristics, the traditional **Reductionist Approach** (fundamental physics/equations) fails because of a lack of defensible criteria for selecting dominant dynamical variables; and **Universalist** approaches (simple mechanisms that apply across a broad spectrum of systems) fail because the simplifying assumptions underlying Universalist models necessarily imply an inability to treat the variability and complexity inherent in the natural environment (external to the system being studied), a particularly striking characteristic of nearshore systems.

In contrast, the modeling and model-testing methodology adopted for this research is in concert with the nonlinear, open nature of nearshore processes. This **hierarchical modeling approach** for nearshore systems partially overlaps with methodologies adopted in physics (e.g., Synergetics: Haken, 1983) and ecology (Hierarchy Theory: Ahl and Allen, 1996), but differs from the former in avoiding the need to use systems of equations as a starting point and from the latter in its emphasis on variable selection via observation and description. It can be summarized with the following four steps:

(i) delineate the boundaries of the open system;
(ii) identify and temporally order dynamical variables of the systems and variables in the external environment affecting the system dynamics;
(iii) for selected levels in this temporal hierarchy, encapsulate the dynamics of faster variables into

a minimal set of rules that relate variables at this level to each other and to the external environment;
(iv) formulate models at these selected levels and derive testable predictions of the models.

Variable selection in the nearshore depends largely on spatial and temporal localization of features and dynamics (e.g., the crests of bedforms), but cannot be predicted from first principles; rather, observations are a necessary step in determining the position of and relationships between variables in the hierarchy. Sensitive tests of models rely on the prediction and measurement of transient behavior, which is a fundamental aspect of natural (in contrast to laboratory) systems. These principles have guided our approach to modeling the nearshore.

BEDFORMS

Following the hierarchical modeling approach outlined above, bedform dynamics were partitioned by time scale into four levels of dynamical variables in a hypothesized hierarchy: (i) mean properties of the bedform field, including mean spacing, mean orientation of crest lines and mean density of defects (the ends of bedform crests); (ii) the position and elevation of individual bedform crests; (iii) the shape and transport patterns on individual bedforms; and (iv) the motion of individual grains and parcels of fluid. With this partition, it became clear that characteristics of bedforms often thought of as static, such as spacing and orientation, should be treated as dynamical variables. A model for the evolution of bedform orientation as a dynamical variable was developed. The model is based on the following simple idea: a field of bedforms can change orientation if the ends of crest lines, the defects, facing to the right migrate at a speed that is different from defects facing to the left. The rate of orientation change is proportional to the number of defects and its form is related to the dynamics of defects, but not to the dynamics of the main part of the bedform. An approximate model for defect migration speeds that applies to a broad range of transport environments permits calculation of the rate of orientation change and the steady-state bedform orientation. For example, for nearshore megaripples migrating at a speed of 0.3m/hr in a storm, the re-orientation time for a 24 degree change in mean current is about 5 hours. Under calmer condition, the re-orientation time can exceed one day, implying that megaripples might not typically be able to respond to tidally-induced changes in flow. Subsequent work has resulted in two potentially important implications: first, megaripple orientation does not respond to wave-driven oscillations in transport, but only to mean transport induced by waves; and second, megaripples probably are oriented normal to mean transport, offering a possible means for remote sensing of transport patterns in the nearshore from bedforms.

BEACH CUSPS

Support for continuing analysis of measurements of beach morphology and swash zone flow during beach cusp formation was provided by this award. The purpose of this set of experiments was to test simultaneously a self-organization model and a standing edge wave model for beach cusp formation. The experiments were supported by a previous award [N00014-92-J-1446].

PUBLICATIONS

B.T. Werner and G. Kocurek (1997) Bedform dynamics: Does the tail wag the dog?, Geology, 25, 771-774.

TK Burnet (1998) Tests of two models of beach cusp formation, Ph.D. thesis, Duke University, Durham, NC.*

BT Werner (1998) Models for beach cusp formation based on self-organization, in preparation for Journal of Geophysical Research.*

TK Burnet, BT Werner and S Elgar (1998) Tests of two models for beach cusp formation, in preparation for Journal of Geophysical Research.*

BT Werner, TK Burnet and S Elgar (1998) Modeled and measured morphological evolution during beach cusp formation, in preparation for Journal of Geophysical Research.*

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SUBJECT: Final Technical Progress Report
ONR Grant Number N00014-96-1-0078
"Modeling Nearshore Processes as Complex Systems"
Principal Investigator: Brad Werner

Enclosed is the final technical report and SF298 for the referenced grant.

Sincerely,

Nancy Wilson

Nancy Wilson
Manager, Contracts and Grants, SIO

Enclosures